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ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

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DETONATING MUNITIONS DIVISION

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A.R.D.E. REPORT (S) 30/57

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RD. 1651. A new ignitory composition for detonators

REVIEW ON Nov 87

F. E. Ball

S. V. Peyton

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Fort Halstead, Kent. ~~RESTRICTED~~ November 1957

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ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

A.R.D.E. REPORT (S)30/57

RD.1651. A new ignitory composition for detonators

F.E. Ball (S2)

S.V. Peyton (S2)

Summary

A new ignitory composition has been evolved, based on lead dinitroresorcinate RD.1337. It is intended to replace Service mixtures containing mercury fulminate.

Lead 2:4 dinitroresorcinate, RD.1337	50 per cent
Barium Nitrate	45 per cent
Tetrazene	5 per cent

RD.1651 composition is somewhat more sensitive to pricking than the Service 'A' and 'B' mixtures. The violence of RD.1651 is similar to that of 'B' mixture, but its power of igniting gunpowder at a distance is intermediate between that of 'A' and 'B' mixtures.

Static trials indicate that RD.1651 is likely to be a suitable replacement for 'B' mixture, and for 'A' mixture in composite detonators. As a replacement for 'A' mixture in igniferous detonatonators, R D.1651 has been found satisfactory in one application, but extended trials will be necessary to establish its general suitability for this purpose.

On hot dry storage RD.1651 shows good thermal stability, and its compatibility with aluminium, copper, brass, tin plated copper and lead azide is of high order. On wet storage, RD.1651 unprotected by waterproofing agents has been found superior to 'A' mixture, and any adverse effects of moist storage on the functioning of RD.1651 detonators is much less than on parallel types containing 'A' or 'B' mixture.

The Report recommends extended trials in representative Service stores, to be filled under production conditions.

Approved for issue:

Ewen M'Ewen, Director.

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1. AR. 514/18/S2

2. Object of the Investigation

The ignitory compositions used hitherto in the British Services for ignition by pricking or by flash have been based on mercury fulminate. Attempts to improve thermal stability have not proved to be very successful and this inherent drawback of these compositions remains.

Compositions containing mercury fulminate also show marked incompatability with aluminium and its alloys, so that the use of such compositions in aluminium shells cannot be tolerated. On the other hand the modern trend towards the use of aluminium for detonator shells is soundly based upon the necessity to eliminate any possibility of the formation of the dangerous decomposition products of lead azide.

It becomes necessary, therefore, to replace compositions based on mercury fulminate with others free from these disadvantages.

3. Scope of the Investigation

Any composition which is to be adopted to replace the present Service compositions must be capable of performing the same functions as the existing A and B compositions. Essential characteristics required are:-

(i) Sensitiveness to pricking must be comparable to that of the current Service A and B compositions. The latter consist of mercury fulminate, potassium chlorate and antimony sulphide in varying proportions.

(ii) The composition must be sensitive towards ignition by flash when used in the receptor role. This is necessary when the composition is used as the top increment in some composite detonators.

(iii) The composition must be compatible with all aluminium alloys and other metals and alloys, particularly copper alloys and tin, with which it is likely to come into contact. It must also be compatible with a wide range of explosives, particularly lead azide, lead nitro-resorcinates (mono-di and trinitro), delay compositions, and secondary explosives.

(iv) The functioning characteristics must not be severely affected by storage under adverse conditions, or by conditions of very high or very low temperature.

The report which follows covers the examination of a composition which appears to offer good prospects of meeting the requirements outlined above. The composition, which has been examined in some detail, has been designated RD. 1651. It has been derived during a series of investigations into the characteristics of compositions based on the lead nitro-resorcinates. The reactive halogen compounds have also been eliminated. The composition is made up as follows:-

Lead 2 : 4 dinitroresorcinate RD. 1337	50%	by weight
Barium nitrate	45%	"
Tetrazene	5%	"

The investigations recorded below examine the use of this composition:

(a) In replacement of Service A and B compositions in igniferous detonators.

(b) In replacement of Service A composition in composite detonators.

4. Experimental Procedure

The experimental procedure has been designed to assess the relevant characteristics progressively brought into operation during the functioning of the detonator. The investigation therefore commences with a study of sensitiveness to pricking, and is followed by an examination of igniting power and ignitability as donor and receptor, and by measurements of pressure developed in the Hopkinson bar, when used in the composite detonator role.

The trials carried out by D/ERDE to establish stability and compatability are reviewed, together with the results of storage under ISAT/and other conditions. Finally the experimental results are discussed in some detail (paragraph 7.).

4.1 Use as a replacement for 'B' composition in igniferous detonators

Tests were carried out using 1.7 grain detonators filled as for Service, design detail FD. 1177, having 0.001 in. lead-tin foil base disc and 0.002 in. brass closing disc. The detonators were varnished internally with cellulose ester varnish in lieu of shellac varnish. The detonators were tested for sensitiveness to pricking and for igniting power.

4.1.1 Sensitiveness to pricking - "Standing striker" method

The detonators were fitted into millboard washers resting upon steel discs, the bases of the detonators being uppermost. A gramophone needle in a small holder was supported with its point in contact with the lead tin foil disc, and a 1 oz. steel ball was dropped freely on to the holder from various heights. The minimum height of fall to give 10 successive firings (100% point) was determined, the height being varied by intervals of 0.25".

Results:	Height of fall 100% point
'A' Mixture detonators (various lots)	2.25" - 3.0"
RD.1651 Detonators filled in A.R.D.E:-	
1st Trial	1.75"
2nd Trial	1.75"
3rd Trial	1.75"

These results appeared to show satisfactory consistency and to be sufficiently promising to merit extended trial, which was carried out by the "falling striker" method.

4.1.2 Sensitiveness to pricking - "Falling striker" method

In this test "free-falling" strikers were used having a 35° true conical point, and of weights 1.0, 1.77, 4.18 ozs. The strikers were dropped from various heights on to the lead-tin-foil disc of the detonators, which were base uppermost and the number firing out of 15 was determined at each height. The results are shown in Table 1. below and expressed graphically in Figure 1. Figure 2 is derived from these results, and shows the energy of impact plotted against weight of needle. Values for the 100% curve for one batch of A Composition are included in Figure 2. It will be seen that for all weights of needle used, RD. 1651 composition is more sensitive than current Service A Composition.

For a given height of fall the velocity of impact is given by the expression $V = 2.31 \sqrt{h}$, where V is in ft/sec., and h is in inches.

Thus, when h = 0.78" $\equiv$ 100% firing with 4 oz. striker.

$$V = 2.31 \sqrt{0.78} = 2.03 \text{ ft/sec.}$$

TABLE 1.

Free falling striker

1 oz striker		1.77 oz striker		4.18 oz. striker	
Height of Fall inches	Number firing	Height of Fall inches	Number firing	Height of Fall inches	Number firing
0.8	3/15	0.4	0/15	0.7	3/5
1.2	12/15	0.6	6/15	0.8	15/15
1.5	28/30	0.8	7/15		
1.6	29/30	1.0	13/15		
1.8	8/8	1.1	15/15		

Confirmation of these results was then sought in collaboration with INO/W, whose assistance in this connection has been much appreciated. INO carried out sensitivity trials on a batch of 1.7 grain detonators filled RD. 1651 made by R.O.F. Chorley. The "free falling" striker method was used with strikers of 30° angle. The results obtained by INO were as follows:-

TABLE 2.

Free falling striker

Weight of striker ozs.	Height of Fall inches	Number fired
1	1.5	30/30
1	1.4	30/30
1	1.3	29/30
4	0.7	30/30
4	0.6	30/30
4	0.5	26/30

Table 3 below summarizes the results obtained during these tests in comparison with previous results with Service A and B compositions. The slight differences observed with the 35°(ARDE) and 30°(INO) needles are not unexpected.

TABLE 3.

Striker Weight Ozs.	Height of drop (inches) 100% firing		
	Compositions		
	A mixture	B mixture	RD 1651
1	1.5 - 2.2	4.1+	1.7, 1.4+
1.5	-	2.5+	-
1.77	1.58	-	1.04
2.3	-	1.5+	-
4	1.0 - 1.2	1.3+	0.6+
4.18	-	-	0.8

+ - Results from INO (W)

4.1.3. Igniting power towards gun-powder pellets

The A.R.D.E. flash test apparatus was used. 1.7 grain detonators, filled as in 4.1 were assembled in a steel holder, resembling the inertia pellet of Fuze No. 158. Beyond the inertia pellet (holder), the flash from the detonator passes down a central tube to ignite a gun-powder pellet which can be supported at various distances along it. The distance between the gun-powder pellet and the detonator was varied to determine the maximum distance at which 10 successive firings of the gun powder pellet occurred. Comparative tests were carried out with detonators containing Service A and B mixtures. The results were as follows:-

Detonator filling	Maximum separation for 100% ignition
RD. 1651	7"
A mixture	9"
B mixture	4"

These results indicate that the igniting power of RD. 1651 is intermediate between that of A and B mixtures.

4.1.4. Igniting power towards delay compositions

Delay times in Fuze 255. Ten fuzes No. 255 fitted with 1.7 grain detonators filled as in 4.1 were submitted to normal delay proof by INO Chorley in comparison with 10 fuzes filled as for Service. The delay times recorded were as follows:-

Detonator filling	Delay times High	Delay times Low	Delay times Mean
RD. 1651	0.0035	0.0010	0.002 secs.
Service filling (B mixture)	0.0120	0.0015	0.003 secs.

Delay times using various delay compositions. The results of trials with a series of delay compositions ignited by detonators containing RD. 1651 in comparison with detonators filled Service B mixture, are recorded in A.R.D.E. Memo. (S) 33/57 "Examination of some Delay Compositions for Use in Q.F. 40 mm. Calibre Gun Fuzes and Similar Systems". The indication of these trials is that RD. 1651 with a suitable degree of confinement is likely to give more regular delay performance than the current Service B mixture.

4.2 Replacement of A Mixture by RD. 1651 in 1.7 grain Detonators

It should be of considerable advantage for all prick detonators used in the Service to have prick sensitivity somewhat superior to that of Service A mixture, and the possibility of its replacement by RD. 1651 in this connection has been considered. A store was sought, therefore, which would present difficult conditions for ignition of a receptor detonator by a flash from a 1.7 grain detonator filled RD. 1651. The L.1.A1 gaine was finally chosen since in this gaine the self-destruction 1.7 grain detonator is required to ignite a 1.8 grain ZY detonator through a somewhat tortuous passage.

A static firing trial was carried out with filled gaines. The shutters were armed and 1.7 grain detonators filled RD. 1651 were fired in their housings by a blow of 5 inch ozs. on to a standing striker resting on the detonator disc. These conditions represent a minimum mouth tamping of the ignitory detonator. Twenty/twenty gaines functioned correctly.

Subsequently these trials were repeated at $-40^{\circ}C$. Twenty/twenty rounds functioned correctly.

A gun trial was then fired with 3.7" shell fitted with VT Fuzes and L.1.A1 gaines. Twenty gaines were fitted with 1.7 grain detonators filled RD. 1651 and twenty with Service A composition detonators. All rounds fitted with RD. 1651 detonators self-destroyed correctly; one Service round was blind.

Subsequently the gun trials were repeated at $-40^{\circ}C$, with detonators filled RD. 1651. Twenty/twenty rounds functioned correctly.

These limited trials show that RD. 1651 is a promising substitute for 'A' Mixture as used in 1.7 grain detonators.

4.3 Use as a replacement for 'A' Composition in composite detonators

4.3.1 5 grain RD. 1651/lead azide detonator. Sensitiveness to pricking

The "standing striker" method described in 4.2 was used for determination of sensitiveness to pricking of 5 grain RD. 1651/lead azide composite detonators. The detonators were closed as in Service with a non-perforated brass disc. 0.002" thick, through which the RD. 1651 composition was pricked. In a series of tests the minimum height required to give ten consecutive firings was found to be 4", and the corresponding height for service 5 grain "A/Z" detonators was 7".

4.3.2 5 grain RD. 1651/lead azide detonator
Ignitability of the RD. 1651 increment

Comparative tests were carried out to assess the ignitability of the RD. 1651 increment when lit from a 1.7 grain RD. 1651 detonator in comparison with the Service 5 grain "A/Z" detonator when lit from a 1.7 grain 'A' detonator.

The tests were carried out on the A.R.D.E. flash test apparatus. The lead azide increments of both types of 5 grain detonators were replaced by inert fillings in order to avoid damage to the apparatus. The flashes from the igniferous detonators passed straight down the central bore of the apparatus to the 5 grain detonators.

Before closure of the RD.1651/lead azide detonator the bare surface of the RD.1651 composition was internally varnished with cellulose ester varnish, while that of the Service type was internally varnished with shellac. Both types were then closed with a paper disc and 4-hole perforated brass disc, and after closure were externally varnished with shellac.

The separation between the igniferous and composite detonators was varied to find the maximum distance which allowed ten consecutive firings of the composite detonators. The values obtained were:-

Igniferous Detonators	5 grain Composite Detonators	Maximum Separation
RD. 1651, 1.7 grain shell, charge average 1.76 grains pressed at 600 lb D.L.	RD. 1651, 1.8 grain antimony sulphide replacing lead azide. Pressed at 1000 lb D.L.	12 inches
'A' composition, 1.7 grain shell, charge average 1.72 grains. Pressed at 600 lb. D.L.	Service 'A' composition, 2 grains, antimony sulphide replacing lead azide. Pressed at 1000 lb. D.L.	10 inches

4.3.3. 5 grain RD. 1651/lead azide composite detonator
Pressure bar tests

Fifty 5-grain Service detonator shells were filled with 2.94 grains of Service lead azide and 1.62 grains RD. 1651, varnished internally with cellulose ester varnish and closed, and finished as for Service (fuze detail 432). The detonators were fired on the pressure bar under standard conditions by needle pricking, and the following pressures were recorded:-

TABLE 4.

Individual Pressures	High	Low	Mean	coeff. of Variation
8.9,8.55,8.65,8.9,8.8,8.5,8.65,8.75,8.7,8.75	9.0	8.2	8.62	2.2%
8.65,8.8,8.95,8.95,8.9,8.7,8.6,8.45,8.4,8.7				
8.55,8.85,8.5,8.5,8.45,8.6,8.4,8.8,9.0,8.75				
8.7,8.5,8.6,8.75,8.4,8.2,8.75,8.35,8.4,8.45				
8.45,8.8,8.65,8.3,8.3,8.45,8.55,8.5,8.7,8.75				

Specification Limits for rejection of Service 5-grain A/Z detonators are:-

Mean = 8.0 tons/sq. in.

Individual low result = 7.0 tons/sq. in.

The mean pressure recorded for accurately filled solid disc ("standard") 5-grain A/Z detonators is 9.3 tons/sq. in.

4.3.4 <u>6.7-Grain RD.1651/lead azide/tetryl composite Detonators Pressure bar tests</u>

Twenty detonators were filled 1.7 grains tetryl, 3 grains Service lead azide, and 2 grains RD. 1651 composition. They were internally varnished with cellulose ester varnish, closed and finished as for Service. They were fired on the pressure bar under standard conditions by needle pricking.

In comparison with the 6.7 grain Service 'AZY' detonators the following pressures were recorded:-

TABLE 5

Type	Individual Pressures	High	Low	Mean	Coeff. of Variation
AZY	9.5,9.7,10.2,9.95,10.05,10.3,10.1,9.65,9.95, 9.55,9.25,9.75,9.8,9.9,9.2,9.4,9.75,9.85,9.55, 10.05.	10.3	9.2	9.77	2.5%
RD.1651 /ZY	9.9,10.05,9.7,9.75,9.75,10.2,10.05,9.9,9.25 9.65,9.65,9.55,9.8,9.8,9.55,9.65,9.6,9.55, 9.55, 9.7	10.2	9.3	9.72	1.7%

5. <u>Stability and Compatability</u>

Trials to establish the stability and compatability of RD.1651 composition have been carried out by D/E.R.D.E. The nature of the trials and the available results are shown in the Appendix, and significant features are summarised in the comments which follow:-

5.1 <u>Chemical Stability</u>

(a) <u>Hot Dry Storage</u>

No measurable change in composition was found after 6 or 12 months storage at 140°F dry; at 18 months a slight drop in the barium nitrate content of nearly 1 per cent was observed, which is thought to be rather more than would be normally expected as the effect of segregation on the sampling.

(b) <u>Hot Moist Storage</u>

In moist trials, the change in the composition is small after 6 and 12 months exposure to ISAT(A) or 140°F 95% RH. In one sample, giving a drop of 7.2 per cent in the LDNR content after 12 months, it was observed on withdrawal that the sample had been wetted by condensation of water in it. In absence of actual condensation the extent of deterioration was less.

5.2 Compatability

With aluminium and its alloys, copper and brass, only very slight corrosive action was observed up to 18 months of hot moist storage. With tin plated copper surfaces and tin-antimony foil, slight corrosion was observed at an earlier stage, but it did not develop progressively as the trial was continued.

Tests with varnishes AZ.21(a) and VM9(a) have not shown any adverse effects on compatability and further tests with VM9(a), RD.1177, and shellac are in progress.

Where mixtures of RD.1651 and Service lead azide in equal proportions have been subjected to hot moist storage, rather variable results have been obtained. A test has shown that in this mixture the rate of hydrolysis of lead azide has not been increased. In contact with aluminium and its alloy AW5 this mixture has only shown very slight corrosion after 15 months hot moist storage.

6. Climatic Trials

6.1 1.7 grain detonators

Detonators filled as in para. 4.1 were put on climatic trial under ISAT/B conditions, both wet and dry. Samples were withdrawn at intervals and were tested for sensitiveness by the falling striker method. The results are shown plotted in Figure 3. The technique employed was based on an original determination of the height of fall of 1 oz. striker at which 14 out of 15 detonators fired. The number of detonators firing out of 15 was then determined at this height for each sample withdrawn.

It will be seen that in the dry trial, the sensitiveness decreased up to 3 months, and then reverted to its original value after 6 months.

In the wet trial sensitiveness decreased continuously over the 6 months' period for which results are available.

6.2 6.7 grain detonators

6.7 grain lugless aluminium shell were filled RD.1651/ZY under normal loading pressures. The surface of the filling was varnished in the normal way, but after closure on to the paper disc no varnish was applied. This condition would emphasize any adverse effects of moist storage on improperly sealed detonators. The detonators were stored at 140°F with 95% Relative Humidity Alternating. Withdrawals were made at periods up to 8 months and after visual examination the detonators were fired on the pressure bar under standard conditions. These detonators were initiated by a striker blow of 3 ft. lbs.

TABLE 6. 140°F 95% FH Alt

Period of Trial (months)	Condition of Detonators			Pressure Tons/sq in	
	Good	Slight discoloration of paper disc	Encrusting of paper disc	Mean	Lowest
0	12	-	-	9.18	8.7
2	1	5	4	8.2	6.55
4	1	7	2	8.28	6.35
6	0	7	3	7.65	5.6
8	0	6	4	6.1	5.1

In view of these promising results a further trial was started in which 6.7 grain AZY and 6.7 grain 1651/ZY detonators in lugless tin-plated copper shell both unsealed as above and sealed with RD.1177, were subjected to the ISAT(B) cycle. Withdrawals have been made up to 6 months and further withdrawals will be made up to 12 months. The results of the pressure bar firings to date are shown in Table 7.

TABLE 7

ISAT(B) Trial

Groups of 10 fired under standard conditions

Period	Sealed or Not sealed	AZY+				1651 ZY*			
		Mean	High	Low	C.V	Mean	High	Low	C.V
Control	S N	9.9 9.65	10.3 10.05	9.5 9.2	2.7 2.7	9.8 9.65	10.2 9.8	9.25 9.55	2.6 1.0
1 month	S N	9.58 2 misfires	10.05 9.75	8.95 3.75	3.1 -	9.83 9.5	10.15 9.9	9.4 9.2	2.3 2.3
2 months	S N	9.5 3 misfires	9.95 9.1	8.85 3.9	3.1 -	9.96 9.4	10.4 9.8	9.5 9.0	2.4 2.6
4 months	S N	9.39 1 misfire	10.05 9.45	8.9 3.6	3.7 -	9.6 9.4	10.1 10.0	8.95 8.75	4.0 4.4
6 months	S N	9.4 5 misfires	9.8 4.8	9.05 3.3	2.5 -	9.38 9.21	9.9 9.8	8.85 8.5	2.9 3.3

+Service filling

*Service increments of lead azide and tetryl; RD 1651 adjusted to permit good closure, nominal charge 2 grains.

All the detonators on trial were examined visually at each withdrawal period and the following observations were made:-

Unsealed AZY detonators

Some corrosion of the detonator shell had occurred after 1 week due to leaching out of potassium chlorate. The corrosion gradually extended over the shell until at 6 months it was a heavy corrosion over the whole external surface of the detonator including the base.

The corrosion at all stages gave a negative reaction for the azide radical.

Unsealed 1651/ZY detonators

After 1 month, there was limited leaching out of barium nitrate and a very slight corrosion on the turn over at the mouth of the detonator. All the paper discs were discoloured by LDNR.

The amount of leaching out gradually increased but at 6 months it was not extensive and the corrosion was slight.

Sealed detonators

After 2 months about 40% of the AZY detonators showed minor leaching out with slight corrosion around the top of the detonator. Some slight increase occurred subsequently, but at 6 months over half the detonators showed no appreciable change in appearance.

No visual change was observed in the 1651/ZY detonators during the 6 months.

7. Discussion

7.1 Sensitiveness to pricking

From the results given in paras. 4.2, 4.3, and 4.7.1. it is clear that the 100% firing point for RD.1651 under the several conditions and weights of striker is at a somewhat lower energy level than for Service 'A' mixture, and the difference would be more pronounced were comparisons made with Service 'B' mixture.

7.2 Igniting power

The igniting power towards gun-powder appears to be intermediate between those of the Service 'A' and 'B' mixtures. There is also evidence that in the lighting-up of delay compositions some improvement in regularity in delay time should be achieved.

Ability to ignite the 1.8 grain 'ZY' detonator appeared to be satisfactory under the conditions of the single instance tested to date; this included static firing and gun trials at normal and low temperatures. This appears to indicate that the RD.1651 composition may prove to be a satisfactory substitute for 'A' mixture in the igniferous detonator, but it is felt that extended trials under other fuze conditions are essential to provide conclusive evidence on this point. This is considered to be particularly desirable in view of para. 7.4 below.

7.3 Flash sensitivity

Considering the results of para. 4.7.2 it is observed that the system RD.1651/RD.1651 appears to show slight superiority over that of 'A' Mixture/'A' Mixture. In para. 4.4 however, it was shown that the igniting power of 'A' mixture towards gunpowder was slightly superior to that of RD. 1651. These results suggest that any slight deficiency of igniting power shown by RD. 1651 in the donor role is more than counter-balanced by superior flash sensitivity in the receptor role.

7.4 Violence and Flash

The degree of violence shown by the RD.1651 composition is obviously a factor of great importance in relation to the requirement mentioned in para. 3(ii), and careful note of this aspect has been taken throughout the experimental work.

The disruptive violence of the composition when filled in 1.7 grain shells is comparable with that of B mixture under similar conditions and the flash appears to be rather more vigorous than that of B mixture. The disruptive violence and the intensity of the flash have been observed to vary much as they do in the case of B mixture. As they are definitely less than those of A mixture, some doubt has been felt of the suitability of RD. 1651 as a replacement for A mixture in igniferous detonators where the flash has to penetrate the service closure of the receptor detonators such as the A/Z and ZY types. In consequence, the trials recorded in para. 4.6 were carried out. These results were quite satisfactory. Here the receptor is a lead azide/tetryl detonator and in the rest trials in para. 4.7.2. a 1651/azide was as good a receptor as an A/Z detonator. It is however, thought that some further trials should be carried out in other fuze systems to establish the use of RD.1651 in this particular role.

In reviewing the desirability, if any, of increasing the power of RD.1651 composition in comparison with Service compositions, it should be borne in mind that the originally higher level represented by mercury fulminate 'A' composition, is subject to considerable deterioration to a much lower level; however, the intermediate power, of the 1651 composition is likely to be maintained for much longer periods under adverse conditions of storage. The results of performance trials of the composition after climatic storage, which are reported under para. 6., are therefore of particular significance.

7.5 Speed of action

RD.1651 composition is likely to show a slower rate of propagation along a column than Service 'A' composition; this may be of significance in the case of fuzes having instantaneous action and which at present are fitted with Service 5 grain 'A'/'Z' type detonator. However, the column of RD.1651 composition in the detonator is quite short, and in fact the difference in functioning time is likely to be very small. Nevertheless, it may be desirable to confirm the acceptability of the position of burst on an appropriate target with rounds fitted with an instantaneous action fuze. From basic considerations it is thought that little of value is to be obtained from static trials directed to this end.

7.6 Power of composite detonators. 5-Grain 'A/Z' type

It will be noted that some slight reduction in the pressure developed on the pressure bar was recorded for the RD.1651/lead azide composite detonator in comparison with the pressures of Service detonators (para. 4.7.3.) This may be associated with the use of a smaller charge of RD.1651 composition. It also has less violence than the Service 'A' composition. The significance, if any, which this might have in relation to adequate initiation of a fire-channel will be resolved during the comprehensive programme of trials with various lead azides which is now proceeding.

7.7 Power of composite detonators. 6.7 Grain 'AZY' type

The close correlation between results (para. 4.7.4.)in both types of detonator (RD. 1651 and Service) demonstrates that the RD.1651/lead azide combination achieved detonation of the tetryl increment to the same order as that obtained with Service 'A' Mixture/lead azide.

7.8 Stability and Compatability

The 18 month period of storage at 140°F dry, continuous, which caused a slight drop in the barium nitrate content corresponds thermally to about $28\frac{1}{2}$ years at 90°F. From this, it would be reasonable to expect a Service life of at least 25 years.

From the analysis of a number of samples of loose RD.1651 withdrawn from different hot moist trials after varying periods, (Appendix Pt.I) it is clear that the effects are small, being limited to falls in the LDNR content of 1 to 2 per cent, a slight fall in the tetrazene content but no appreciable effect on the barium nitrate. Where however, the composition has been wetted by condensed moisture, the fall in LDNR+content reached 7%, after 12 months under severe conditions. With RD.1651 pressed into aluminium shell, similar results were obtained.

The results shown in the Appendix, Pt. 2(a) (b), indicate a high degree of compatibility of RD.1651 with aluminium and its alloys, copper and brass and the varnishes tested. Tin- plated copper, although slightly more susceptible to corrosion, is also regarded as acceptable for use with RD. 1651.

As material for detonator closing discs , a tin-antimony alloy has been found much superior to Service lead/tin foil in regard to corrosive action.

The variable results, Appendix, Pt. 2(c), obtained with the mixtures of lead azide and RD.1651 are thought to be associated with the degree of wetting of the sample by condensation. It is evident, however, that barium nitrate is the ingredient most likely to be affected by contact with lead azide. In composite detonators where the contact would be restricted to the interface, the effects would be on a much lower scale. As no increase in the rate of hydrolysis in this mixture has been found, the presence of RD.1651 in composite detonators should in no way affect the decomposition of the lead azide.

7.9 Climatic Storage

The effect of storage on the prick sensitivity of the composition and on its effectiveness in composite detonators was investigated. For the first case, 1.7 grain detonators were tested (6.1). As the Service closure of these detonators is not 100% waterproof, they were submitted to the ISAT(B) cycle both dry and wet. The dry cycling reduced the sensitivity at first but it had recovered at 6 months, so that the overall effect is not considerable. With wet storage, there is a gradual reduction of sensitivity and at 6 months it is estimated that the height of drop required for 100% firing would have increased from the original value of 1.7 inches to a value around 2.5 inches. This behaviour is very much better than A or B composition which would be expected to become insensitive after 4 months ISAT(B) dry and after 2 months at ISAT(B) wet.

In the first trial of composite detonators, 6.7 grain aluminium shell were filled 1651/ZY. In order to provide very drastic conditions they were not sealed and were stored at 140°F, 95 per cent relative humidity alternating. None of the detonators failed to fire and the fall off in pressure could be expected from the effect of the moisture on the rest of the filling.

In the subsequent trial still in progress, results are available up to 6 months for 6.7 grain tin-plated detonators with A mixture and RD.1651, both sealed and unsealed on the ISAT(B) cycling. In the unsealed condition the presence of A mixture gave rise to heavy corrosion of the detonator shell, some misfires and low pressures whereas RD.1651 gave only slight corrosion, no misfires and normal pressures. In the sealed condition, about half the A mixture detonators showed slight corrosion but the pressures were comparable to results with RD.1651. It would appear that if a detonator is not properly sealed, it would have a much better life with RD.1651, than with A mixture; since after 6 months 50% of the AZY type misfires.

8. Conclusions

8.1 The 100 per cent firing point for RD.1651 under the various weights of striker tested is at a somewhat lower energy level than for 'A' mixture, so that its prick sensitivity is better than that of 'A' or 'B' mixtures.

8.2 The violence of RD.1651 is similar to that of 'B' mixture, and it shows an igniting power for gunpowder intermediate between that of 'A' and 'B' mixtures, so that RD.1651 should be an effective replacement for 'B' mixture.

8.3 In the composite type detonator RD.1651 would appear to be a suitable replacement for 'A' mixture.

8.4 As a replacement for 'A' mixture in igniferous detonators, RD.1651 appears to be satisfactory in the single application tested so far, but extended trials will be necessary to establish its general suitability in this role.

8.5 Compatibility of RD.1651 with aluminium, copper, brass, tin-plated copper and lead azide has been found to be of high order.

8.6 On hot dry storage RD.1651 shows good thermal stability, and should have a long Service life.

8.7 On wet storage, the absence of potassium chlorate from RD.1651 greatly reduces any external corrosive action resulting from minor leaching of the constituents.

8.8 Any adverse effect of moist storage on the functioning of an RD.1651 detonator will be much less than on parallel types containing 'A' or 'B' mixture, under similar conditions.

9. Recommendations

It is considered that the results given above justify extended trials in representative Service Stores, and it is recommended that such trials to confirm the suitability of RD.1651 as a replacement in the following detonators:-

(a) 'B' mixture igniferous detonators

(b) 'A' mixture igniferous detonators

(c) Composite-type detonators

should be arranged.

It is anticipated that the factory filling programme made necessary by these trials will afford data on which to assess safety aspects and handling characteristics of the composition under production conditions.

10. Acknowledgements

The authors thank Mr. H.L. Porter for the assistance he has given in the experimental determination of sensitiveness to pricking under free-falling striker conditions; also Mr. P. Bessent (lately Head of the Initiation Section) for supervision of work (particularly on the pressure bar) at Fort Halstead, and for collaboration in the preparation of this Report.

The authors wish to place on record the valuable assistance received from D/E.R.D.E. with whom close contact has been maintained throughout. Mr. G.W.C. Taylor has been responsible for the method of preparation, and manufacture of the lead dinitroresorcinate RD.1337 used in the RD.1651 composition. Mr. H. A. Sayce undertook the laborious assessments involved in determination of the chemical stability and compatibilities of the composition during prolonged periods of test.

Thanks are due also to I.N.O. Woolwich for help in determinations of sensitiveness to pricking by the free-falling striker method, and for the sustained interest he has shown in this work.

11. References

Taylor, G.W.C. and White, J.R. "The Manufacture of Lead Dinitroresorcinate composition RD.1337". E.R.D.E. Report No. 3/R/55.

Griffiths, N., "Examination of some Delay Compositions for Use in Q.F. 40 mm. Calibre Gun Fuzes and Similar Systems". A.R.D.E. Memorandum (S) 33/57.

APPENDIX

STORAGE TRIALS OF RD. 1651 COMPOSITION

(INFORMATION SUPPLIED BY D/ERDE)

Trials with the loose composition

1. Chemical stability

Purpose of Trial	Conditions of Storage	Period of Storage	Remarks
Thermal stability	$140^{\circ}F$ dry continuous	6 months	Analysis of separate ingredients show no measurable change.
		12 months	As 6 months.
		18 months	Barium nitrate content reduced by nearly 1 per cent. No other change.
Effects of moist storage on loose composition fully exposed.	ISAT(A)	12 months	LDNR content reduced by 2 per cent.
	$140^{\circ}F$. 95% R.H. alternating	6 months	LDNR content reduced by 1 per cent.
		12 months	LDNR content reduced by 7.2 per cent. Tetrazene content reduced by 3.4 per cent.
Effects of moist storage on composition pressed into aluminium shell, fully exposed.	$140^{\circ}F$ 95% R.H. alternating	6 months	LDNR content reduced less than 1 per cent.
		12 months	LDNR content reduced less than 1 per cent.
		18 months	LDNR content reduced by 4.4 per cent.

2. Compatibility

(a) with metals

Purpose of Trial	Conditions of Storage	Period of Storage	Proposed duration of Trial.	Result
Compatibility with pure aluminium (SIA grade) 99.8% and aluminium alloy AW5.	1) ISAT/A 2) 140°F 95% RH alternating.	18 months	2 years	Very mild corrosive effects only have developed on the metal specimens, this being first detected at the 12 months' stage; both pure aluminium and aluminium alloy AW5 are regarded as compatible. (Note 'A' composition is considered entirely incompatible with all forms of aluminium).
Compatability with copper, brass. tinned copper and tin/antimony (92/8) alloy.	140°F. 95% RH. alternating.	16 months	2 years	Copper and brass may be regarded as compatible With tin surfaces there is a slight corrosive action, first detected after 9 months' storage, which takes the form of the development of clusters of small bubbles, in patches, over the exposed metal surface. With tinned copper, this has caused lifting of the plating at one very small spot on each of the specimens under test; it has not caused puncturing of the tin/antimony foil specimens (0.005" thickness). This effect remains slight, even on subsequent storage at these drastic test conditions, but it is possible that it might give rise to embrittlement and splitting of the tin/antimony alloy if used for closing discs (0.001" thickness foil) for detonators. (Note 'A' composition has been found to produce serious corrosive action on tin surfaces within two to three weeks at similar conditions of storage.)

(b) <u>with varnishes, cements, etc.</u>

Purpose of Trial	Conditions of Storage	Period of Storage	Proposed duration of Trial	Result
(a) Compatibility with Vinylite varnish AZ 21(a)	140°F. 95% RH alternating	10 months	18 months	(a) Assessment by analysis not yet available but a limited number of small black patches visible on the treated surface of the composition, first detected after 4 months storage, indicates possible slight decomposition.
(b) Compatibility of the composition, treated with varnish AZ 21(a), with pure aluminium and tinned copper.				(b) No adverse effects detected with pure aluminium, but the first slight corrosive effects are visible on tinned copper, after 9 months' storage, which involve lifting of the plating at one or two places around the extremities of the RD.1651/varnish layer; the extent of the corrosion remains very slight at this stage, however. (Note. 'A' composition has not been tested with this varnish in contact with tinned copper, but it is known to produce serious corrosive action alone on tin surfaces within two to three weeks at similar conditions of storage.)
(a) Compatibility with varnish VM 9(a)	-do-	4 months	(do)	(a) No visual effects to date; assessment by analysis to be made after longer storage.
(b) Compatibility of the composition, treated with varnish VM 9(a), with pure aluminium and tinned copper.				(b) No indication of corrosion of the exposed metal surfaces is evident to date.
Compatibility with Aero Research Adhesives (or Araldite Cements): "100/30" type, 2000 S, 2000 N and 2500.	140°F. 95% RH continuous	2 months	2 months	Not yet available.

(c) with other initiators, viz: lead azide

Purpose of Trial	Conditions of Storage	Period of Storage	Proposed duration of Trial	Result
Compatibility with Service lead azide; the loose compositions, mixed intimately with each other in equal proportions by weight, to be subsequently examined for: (a) effects on the ingredients of RD.1651	(a) 140°F 95% R.H. alternating	(a) 3 months 6 months 9 months	(a) 12 months	(a) LDNR reduced by 0.3 per cent. Barium nitrate by 5.2 per cent. LDNR reduced by 2.8 per cent. Barium nitrate by 7.6 per cent. LDNR reduced by 0* per cent. Barium nitrate by 4.9 per cent. No definite effects on tetrazene detected.
(b) effect on the hydrolysis of lead azide	(b) with added distilled water at 120°F	(b) 17 hours	(b) 17 hours	(b) the hydrolysis of lead azide is not enhanced; in fact, a slight decrease in the rate of the hydrolysis has been measured.
Compatibility of a mixture of RD.1651 and Service lead azide with pure aluminium (S1A Grade) and aluminium alloy AW5; this combination is designed to simulate, but to a more drastic degree, the condition of a composite filling in an aluminium detonator.	140°F 95% RH alternating	15 months	2 years	Very mild corrosive effects only have developed on the metal specimens; both pure aluminium alloy AW5 are regarded as compatible with this mixture.

*No fall in LDNR detected; possibly associated with some variation in the extent of moisture deposition by condensation.

FIG. I.

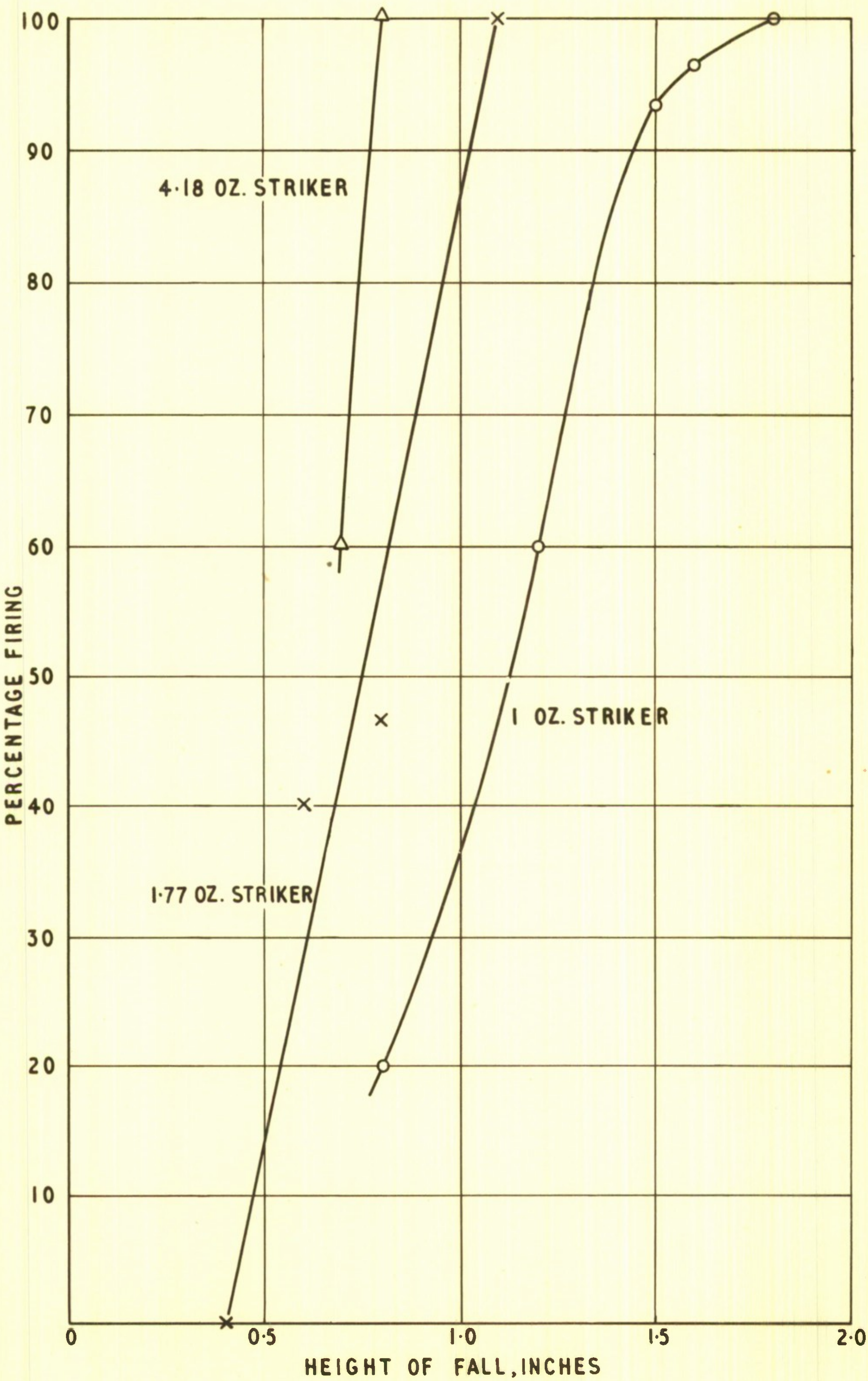

FIG. I. SENSITIVENESS OF 1·7 GR. RD. 1651 DETONATORS TO FALLING STRIKERS

FIG.2.

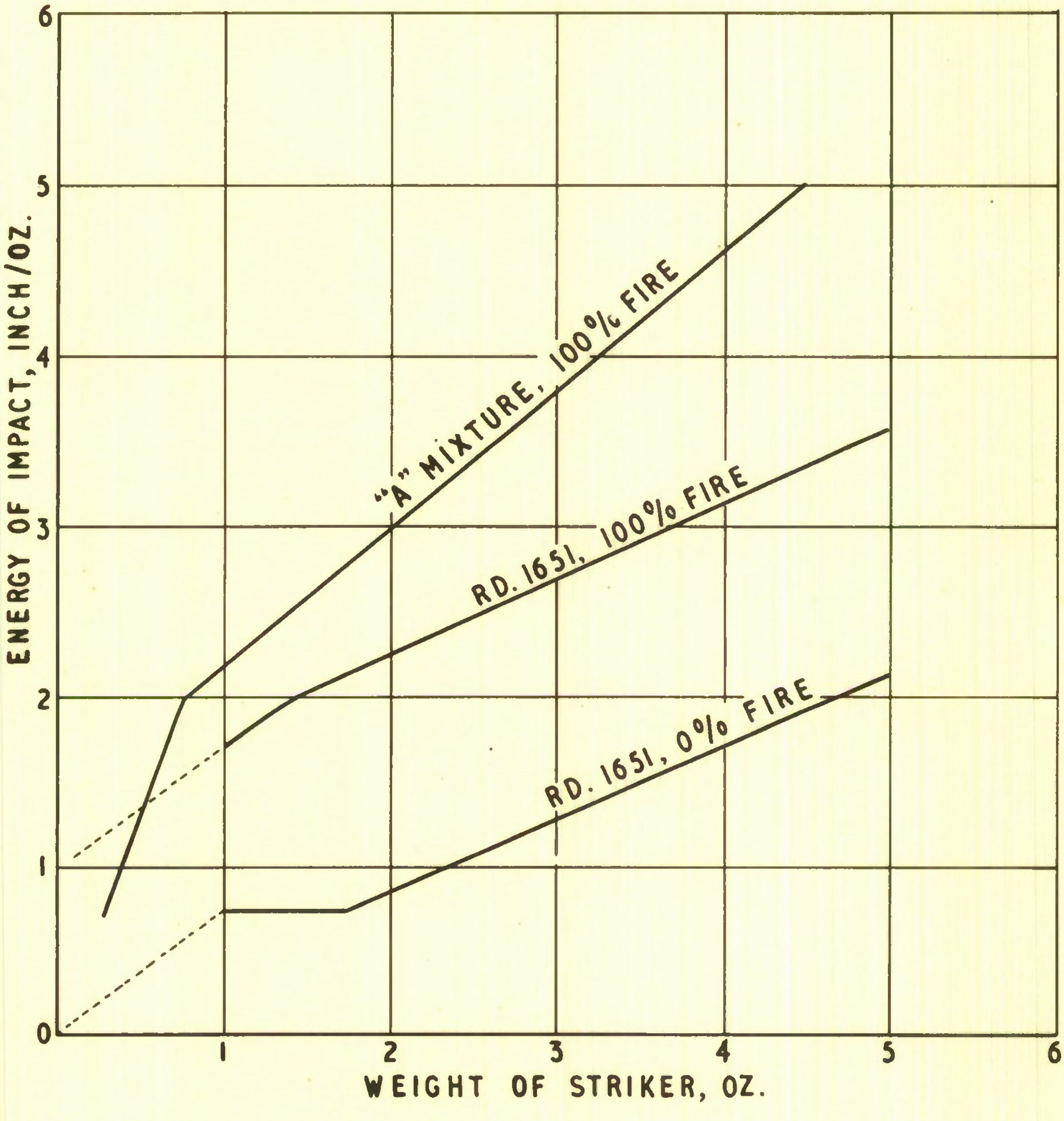

FIG. 2 SENSITIVENESS OF 1·7 GR. DETONATORS TO FALLING STRIKER:- ENERGY CURVES

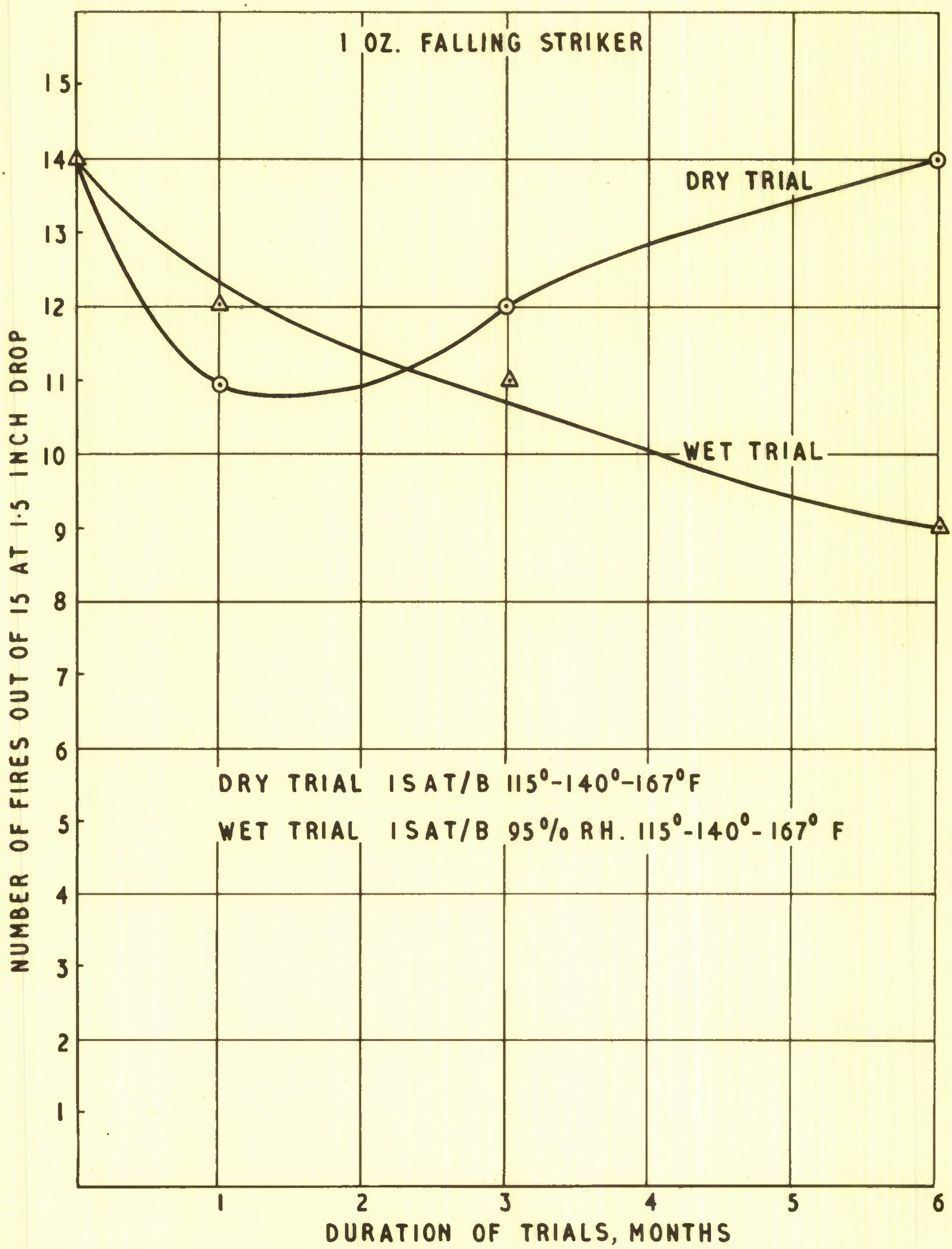

FIG. 3 SENSITIVENESS OF 1·7 GR. RD.1651 DETONATORS AFTER CLIMATIC TRIAL

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Armament Research & Development Establishment — 662.41 RD 1651:
A.R.D.E. Report (S)30/57 — 662.41 Lead DNR

RD.1651. A new ignitory composition for detonators
F.E.Ball, S.V.Peyton. — November 1957

A new ignitory composition has been evolved, based on lead dinitroresorcinate RD.1337. It is intended to replace Service mixtures containing mercury fulminate. The composition is designated RD.1651 and consists of:-

Lead 2:4 dinitroresorcinate, RD.1337	50 per cent
Barium Nitrate	45 " "
Tetrazene	5 " "

RD.1651 composition is somewhat more sensitive to pricking than the Service "A" and "B" mixtures. The violence of RD.1651 is similar to that of "B" mixture, but its power of igniting gunpowder at a distance is intermediate between that of "A" and "B" mixtures.

Static trials indicate that RD.1651 is likely to be a suitable replacement for "B" mixture, and for "A" mixture in composite detonators. As a replacement for "A" mixture in igniferous detonators, RD.1651 has

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The Report recommends extended trials in representative Service stores, to be filled under production conditions.

18pp. 3 figs. 7 tabs. 2 refs.

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